Effects of oblique impacts on catastrophic disruption of rocky bodies simulated by quartz glass

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Planetary collisional process is one of the most important physical processes in the solar system, especially for the planetary formation process in the solar nebulae. Because of the importance of the physical process and the implications for the origin of asteroids and other small bodies, impact disruption experiments have been conducted for several decades, and rocky materials such as basalt and glass etc. were used for these impact experiments. Then, the impact strength defined by the specific energy (Q) necessary for the catastrophic disruption was obtained for these rocky materials, and most of the impact experiments were conducted by head-on collisions, so that the impact strength was usually applicable only for the head-on collision. However, collisions among planetary bodies are well known to be not only head-on collision but also oblique collision, and actually the impact angle of 45 degrees is the most probable impact angle in the solar system. Therefore, it is necessary to study the impact strength for the oblique impact and to clarify the effect of oblique impact on the collisional disruption of rocky bodies.
In this study, we conducted the impact experiments of quartz glass at the impact angle from 90 (head-on collision) to 0 (glancing impact) degrees, and studied the effect of oblique impacts on the degree of disruption and the ejection velocity of the ejecta fragments. We used quartz glass spheres with the size of 5cm and 8cm for the target, and a polycarbonate spherical projectile with the size of 4.75mm was launched at the impact velocity from 2 to 6km/s. The oblique impact was made at 15 to 90 degrees at 4.3km/s under the vacuum condition of 20Pa. After the impact, all the impact fragments were recovered to measure each weight in order to construct the size distribution of these fragments.
We found that the largest fragment mass was almost constant at the impact angle from 90 to 60 degrees, and it suddenly decreased from 60 to 45 degrees for the 5cm target, and then gradually increased up to 15 degrees: the largest fragment mass at 45 degrees was one order of magnitude larger that obtained from the impact between 90 and 60 degrees. Although the impact strength could be strongly affected by the impact angle at the high obliquity smaller than 45 degrees, the modified specific energy (Q_c) defined by the normal component of the impact velocity on the impact surface was an appropriate parameter to scale the impact angle on the degree of the impact disruption, then the impact strength (Q^*) could be refined by using this modified specific energy, Q_c: The obtained impact strength defied by Q_c including the oblique impacts is 1110 J/kg for the quartz glass. We also found a very unique feature on the quartz glass during the disruption, that is, the severe disruption and high velocity ejecta was discovered at the antipodal region. The mass of disrupted fragments originated from the antipodal region was almost same as that was originated from the cratered region near the impact site. This might be caused by the severe concentration of the shock wave at the antipodal region and it would be reflected on the free surface with the perfectly spherical shape of the quartz glass. But, further research would be necessary to understand this unique features discovered at the antipode.

Keywords: catastrophic disruption, oblique impact, impact strength

